R&D FACILITY

facts

Department of Energy
Office of Fossil Energy
Federal Energy Technology Center

GAS STREAM cleanup
PROJECT

Numerical Modeling of Circulating Fluid Bed (CFB) Systems

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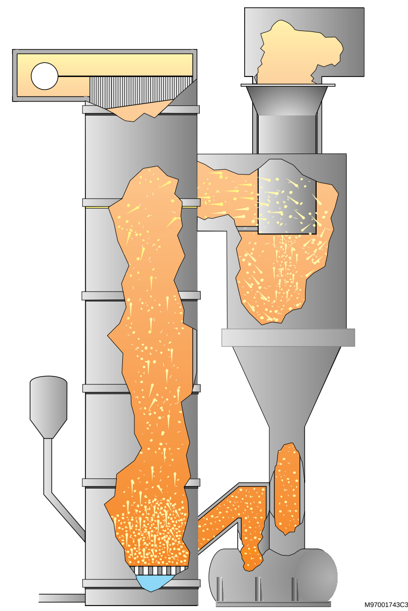
FETC

Capabilities

The objective of developing these models is to aid CFB operations in analysis of existing plants, optimization of plant operations, and evaluation of new designs. FETC is using these models: to solve problems encountered during shakedown,
to optimize process units, and to address new issues as they arise.

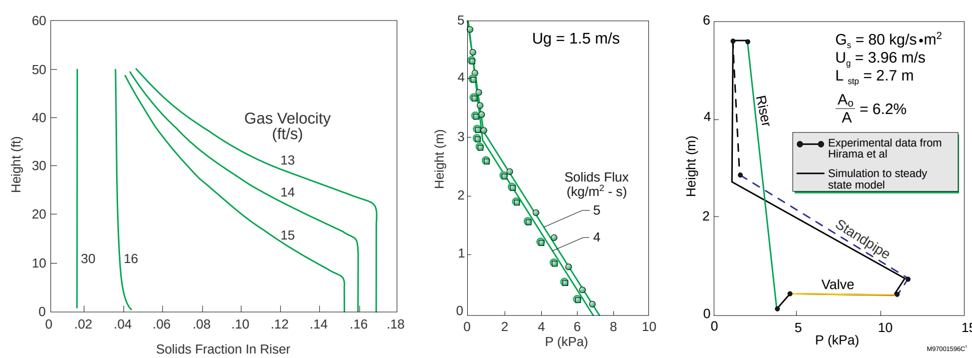


Circulating Fluid Bed Process

Steady-State CFB Model: A versatile steady-state model was formulated by integrating a set of relationships selected from published results. The model predicts the solids distribution and operating regimes from given system parameters, particle properties, and gas flow rates. It is constrained by imposing pressure and mass balances. The model encompasses three operating regimes:

- ***Riser fluid regime*** from fast fluidization ($\varepsilon = 0.75$) to dilute transport ($\varepsilon = 0.99$) modes.
- ***Standpipe operations*** from packed-bed ($\varepsilon = 0.37$) to fluidized-bed ($\varepsilon = 0.75$) modes.
- ***Control of circulating solids*** by mechanical and non-mechanical valves.

The steady-state model was validated against available literature. A series of sensitivity tests on all the controlling variables was conducted to generate a gain matrix to use in the dynamic model. The Transport Reactor Development Unit coal gasifier, operating in Grand Forks, North Dakota, was successfully simulated, determining the standpipe operating regime and solids circulation rates and constraints, and predicting the optimal aeration rates for stability and performance.



Validation of Steady State solid and pressure profiles
and pressure balance against literature data

Numerical Modeling of Circulating Fluid Bed (CFB) Systems

Capabilities (continued)

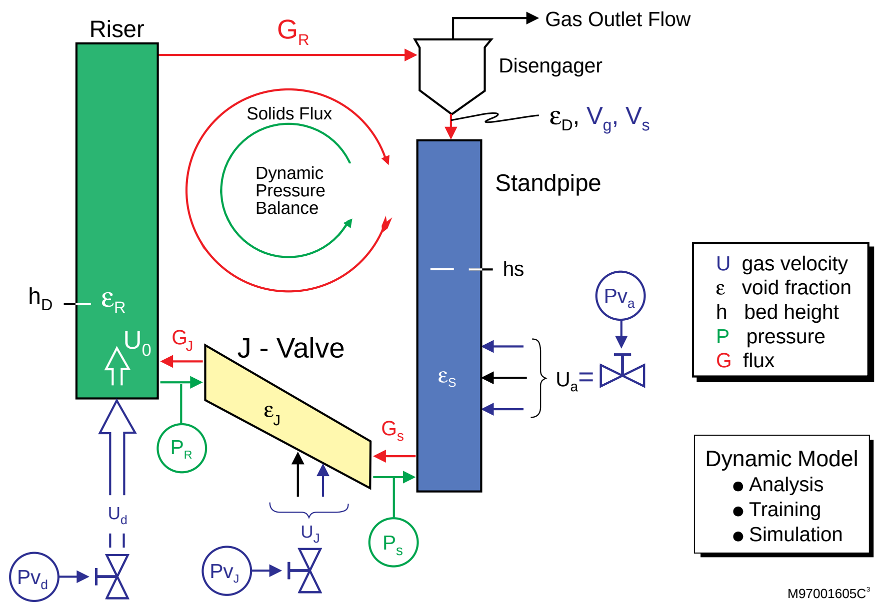
Dynamic CFB Model: The time-dependent interactions of two-phase flow and pressure balance around the integrated circulating loop introduce the potential for dynamic instabilities and sub-optimal performance. Dynamic models are being developed to simulate the solid and gas fluxes and the mechanisms that couple components of the circulating unit. A spatial- and time-dependent model has been formulated using a gain matrix generated from the steady-state CFB model to evaluate transient behavior in real-time. Based on stirred reactor dynamics, redistribution of solids around the transport components are found to exhibit a finite propagation delay and first-order time constants. The dynamic analysis techniques couple the transient characteristics for all components, thus simulating the dynamic instabilities that make operational control of circulating reactors such a challenge. One-dimensional lumped parameter models of the riser and standpipe have been developed and compared to the steady-state CFB model.

Future Activities: Steady-state models will be enhanced to include combustion and gasification chemistry along with the associated energy balance. Dynamic models will be developed that integrate solids control valves with the riser and standpipe. The model validation efforts will be augmented using highly instru-mented, transparent-walled, cold-flow units. Both steady-state and dynamic models will be made available on the internet.

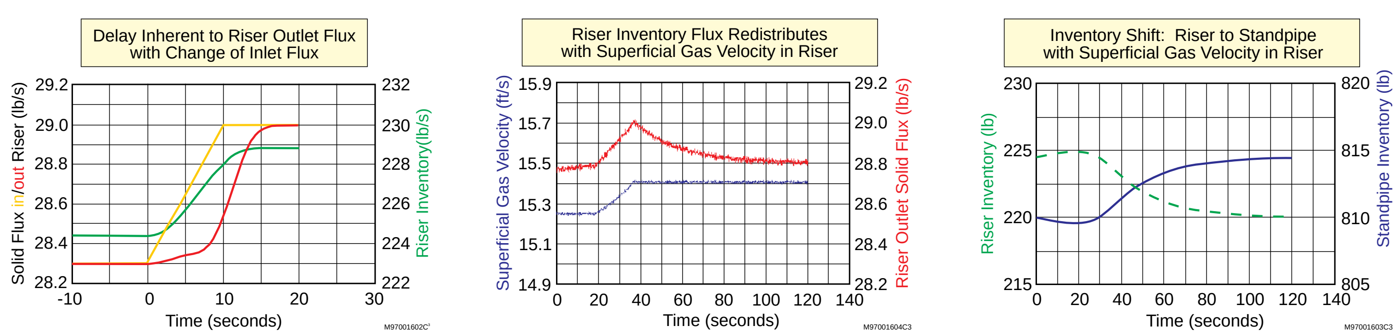
Opportunities

The dynamic models are being developed to execute in real-time to serve as a trainer and dynamic-process simulator. A PCTRACS version is planned for use in systems studies. Evaluation and analysis of CFB systems are available to power plants and other interested companies.

Dynamics of Integrated Control



Components of Circulating Fluid Bed System



Dynamic model of CFB Loop and predicted delays in Riser solids flux